

HYBRID FLOW METERING VALVE

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BACKGROUND OF THE INVENTION – FIELD OF INVENTION

[0001] The present invention relates generally to fluid flow valves and more precisely pertains to fine regulation metering valves and especially to the valves that can provide extremely precise regulation over a large range of regulated flows.

[0002] Description of the Prior Art

[0003] When accurate control of relatively low flow rates is required it is wide spread practice to employ needle valves for this purpose. Different types and improvements of the needle valves serve well this purpose because of the fine adjustment and accurate control provided by such valves.

[0004] For regulating extremely low flow the needle valves are used with very small orifice and literally needle type of stem - US Patent No 5,687,949 issued to Dukas et al, US Patent No 3,910,553 to Boylan, US Patent No 4,311,170 to Dolan. This needle is providing gradually changeable annular space between the stem and the seat of the valve. The maximum flow is restricted by the internal diameter of the seat. Despite of other improvements like spring supported seat, aiming to stabilize the functioning - US Patent No 4,500,068 to Ramundsen et al, it is obvious that such limited space for the flow passage can tolerate very narrow interval of low fluid flows.

[0005] The same drawback - regulation of only low flow in a narrow interval - characterizes low flow valves having regulating notches or passages such as US Patent No 4,406,442 to Bettin et al. Even with shut-off function the valve is capable to provide regulation in a very narrow interval. The flow-dynamic resistance of those valves is high and limited by the full bore of the created orifice.

[0006] In a more complicated construction - fine grooves with adjustable length are used for regulating very low flows US Patent No 4,495,965 and US Patent No 4,340,234 to Ise. Despite of the claim that the valve can regulate big flow range, this range is still limited by the naturally small cross-section of the groove compared to the inlet and outlet cross-sections.

[0007] For fine adjustment of the low flow, valves utilizing flexible tubing compressed by specially shaped surfaces US Patent No 4,171,006 to Steere Jr. and US Patent No 2,827,919 to Rice are suggested. Drawback of those devices is the deviation of the adjusted flow at any new position due to the memory of the plastic tubing and inconsistency of the flow (due to the mechanical properties of the plastic or resin) changing with the temperature of the fluid.

[0008] Based on similar principals, valves with cone-shaped stem are also referred as needle valves US Patent No 5,249,773 to Feld, US Patent No 5,244,182 to Pacht, with some decreased accuracy but used with higher flow rates. Those types of cone/needle valves are more appropriate for the moderate range of flows but fail to provide fine regulation in a very low flow mode. Their highest flow rate is still limited by the bore of the orifice, which is always smaller than the full bore of the inlet/outlet of the valve therefore providing additional flow resistance.

[0009] It is known from the prior art that the valves with capability of providing full flow, or ball valves, or hollow cylinder as a stem, are well accepted to regulate roughly high flows but completely fail to provide fine regulation. One skilled in the art knows that for each range of flow, valve with different construction and respective accuracy is used. The known art does not provide a valve with fine regulation and especially metering capability for very high, moderate and very low flow ranges all together.

[0010] Objectives and advantages

[0011] It is a primary objective of the present invention to provide a solution for smooth, fine, accurate and repeatable regulation and measuring function over a broad range of flows. The low range must start from zero and the top range is to be limited by the full-bore opening of the inlet/outlet of the valve. Such valve will provide regulation over a flows ranging up to four orders of magnitude.

[0012] Another object of the present invention is to exploit different designs having the same basic concept, functions and abilities, but serving different needs thereby to develop a family of valves having same theoretical and functional background.

[0013] Consecutively another object of the present invention is to provide easy technologically achievable solutions for manufacturing such family of valves as well as materials for building such valves. Further objects and advantages of the present invention will become apparent from consideration of the drawings and ensuing description.

SUMMARY OF THE INVENTION

[0014] The present invention provides a novel apparatus for fine regulation of flow incorporating a body tubular inside. One substantial portion of that tubular space is internally threaded and a cylindrical stem with corresponding thread engaged in it. This portion is designated as moving (guiding) portion. Another substantial portion of that tubular inside space is connected to two ports – inlet and outlet. The inlet port axis is perpendicular to the tubular space axis. The outlet axis is either perpendicular or the same as a tubular one. The inlet and outlet are separated by substantial distance which is designated as regulating portion of the tubular space.

[0015] Important characteristic of the present invention is that the cross-section of the inlet and outlet ports is slightly smaller than the cross-section of the tubular regulating portion. This way the fluid passage between the two ports has no restrictions when the valve is fully opened. Part of the stem is proliferated from the moving portion to the regulating portion. The part of the stem which is engaged into the regulating portion of the tubular body has

length slightly bigger than the distance between inlet and outlet ports, thereby to be able completely to fill the regulating portion when the stem is fully extended between two ports and to close the inlet port.

[0016] Further, one or both of the engaged into regulating portion two surfaces - the tubular one and the surface of the stem - are threaded. When both of them are threaded, the pitch of the thread is the same as the pitch of the threads in the moving portion. In a regular thread irrespective of its class of tolerance, there are two helical capillary channels along the threaded line. One of them - between the external thread root and internal thread crest - is specified as "root clearance". The other - between external thread crest and internal thread roots - is specified as "crest clearance". The purpose of those clearances is to provide capillary space for lubrication and to facilitate the manufacturing of the threaded parts. However, threads without those capillary channels can provide very tight fit. In case where one or both of the threads are truncated with tapering truncation, one or both of those clearances will change their cross-section along the thread providing fluid path with tapering longitudinally cross-section. This concept is adopted to form flow path with mentioned longitudinal change.

[0017] Further, one or both threaded surfaces in the regulating portion have their thread substantially truncated. For the body this truncation is tapering from the major diameter of internal thread to diameter smaller than minor diameter of internal thread. For the stem the thread is truncated tapering from the major diameter of external thread to diameter smaller than the minor diameter of external thread. This way when the stem and body threads are engaged, a grove with gradually changed cross-section is formed along the backlash of the joined thread. The distance of this tapering truncation is shorter than the distance between two ports – inlet and outlet.

[0018] The end of the regulating portion of the stem extends further from the truncated thread and tapers as cone or ogival bullet-shaped surface. This surface, when the valve is completely closed, seals matching annular surface seat on the axial port. When the "shut-off" function is not necessary, the axis of both ports can have an angle with the axis of the tubular body. The valve is operating by rotating the stem thereby moving the stem in the regulating portion "in" or "out".

[0019] By slightly rotating backward from “shut-off” position, capillary-looking backlash is formed along the truncated or tapered thread. The length and average cross-section of this backlash is proportional to the length of the inserted into regulating portion stem. Very fine regulation for the very low flows is achieved. By further rotation of the stem the shape and volume of the front ogival surface of the stem is acting more similarly to the needle valve, performing very fine regulation of moderate flow. Finally the stem is engaged with its tapering part providing regulation only as conical valve until the space between the two ports is completely free. The valve is completely opened and has very low fluid-dynamic resistance.

[0020] Term “thread” in this case should be understand largely rather than the standard technical use, as a spiral groove not necessary defined by regular pitch, and applied to any profile of the thread – triangle, square, rectangular, trapezoid, oval, semicircle etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The foregoing and other features and advantages of the present invention will be apparent from the detailed description of the present invention contained herein below, taken in conjunction with the drawings where

[0022] FIG.1 is a sectional view of the flow metering valve with threaded regulating portion of the stem and the body;

[0023] FIG.2 is a sectional view of the flow metering valve assembly with threaded regulating portion of the stem and tapering regulating portion of the body;

[0024] FIG.3 is a sectional view of the flow metering valve with threaded regulating portion of the stem and smooth regulating portion of the body;

[0025] FIG.4 is a schematic of generic valve embodiment illustrating four phases of action of the valve upon present invention:

[0026] FIG.4-A fully closed valve – shut-off position

[0027] FIG.4-B low flow position of the stem

[0028] FIG.4-C moderate flow position of the stem

[0029] FIG.4-D high flow position of the stem;

- [0030] FIG.5 is a schematic cross-section along the axis of a generic valve demonstrating a variety of possible fluid paths;
- [0031] FIG.5-A is a schematic of the stem and body both with truncated threads and sealing seat in the body
- [0032] FIG.5-B is a schematic of the tapered truncated thread on the stem and regular thread on the body
- [0033] FIG.5-C is a schematic of smooth body and stem with tapering crest of the thread
- [0034] FIG.5-D is a schematic of smooth body and tapering truncated thread of the stem
- [0035] FIG.5-E is a schematic of smooth body and tapering square thread
- [0036] FIG.5-F is a schematic of smooth body and tapering rounded profile thread;
- [0037] FIG.6 is a section of the body or body insert with view of the inserted stem with threaded tapering sabot in low to moderate flow position;
- [0038] FIG.7 is a sectional view of the valve assembly with stem having separated leading thread from the regulating thread by thin neck;
- [0039] FIG.8 is a sectional view of the valve with tapered thread on the regulating part of the stem and smooth bore regulating portion of the body;
- [0040] FIG.9 is a sectional view of the full in-line assembly of the preferred embodiment of the valve in which the moving part of the stem is separated from the regulating part by cylindrical portion and seals – o-rings;
- [0041] FIG.10 is a sectional view of the full in-line assembly of the preferred embodiment of the valve having stem and body with leading threads and non-threaded regulating part of the body.

REFERENCE NUMERALS

- [0042] 20. Stem
- [0043] 20A. Conical/ogival front sealing part of the stem
- [0044] 20B. Regulating portion of the stem
- [0045] 20C. Threaded portion of the stem with leading thread
- [0046] 20D. Non-threaded cylindrical part of the stem
- [0047] 20E. Groove for O-ring on the stem

- [0048] 20F. Sealing surface of the stem
- [0049] 20G. Thin neck portion of the stem
- [0050] 21. Regulating sabot - part of the stem
- [0051] 22. Body of the valve
- [0052] 22A. Regulating portion of the body
- [0053] 22B. Body-insert
- [0054] 22C. Smooth bore portion of the body or insert between leading and regulating portions
- [0055] 22D. Sealing surface of the seat in the body or the insert
- [0056] 22E. Threaded part of the body with leading thread
- [0057] 24. Bonnet
- [0058] 25. Packing nut
- [0059] 26. O-ring
- [0060] 27. Packing seal
- [0061] 30. Micrometer handle
- [0063] 32. Vernier handle
- [0064] 34. Scale-barrel
- [0065] 35. Micrometer barrel
- [0066] 36. Union nut
- [0067] 38. Screw lock of the handle
- [0068] 40. Fluid path – passage formed along regulating portion of the thread
- [0069] 41. Inlet port
- [0070] 42. Inlet coupling assembly
- [0071] 43. Outlet port
- [0072] 44. Outlet coupling assembly
- [0073] 45. Annular space around the stem connected to outlet port

DESCRIPTION AND FUNCTION OF THE MAIN EMBODIMENTS

[0074] Referring more particularly to the drawings wherein the showings are for the purpose of illustrating the invention only as well of explaining its function, and not for the purpose of limiting the same.

[0075] A common in all embodiments on FIGS. 1, 2, 3 and FIGS. 6, 7, 8, 9, 10 is a valve having body 22 with longitudinal tubular cavity. Portion of this cavity is threaded with thread designated as leading thread 22E and regulating portion 22A. The two sides of regulating portion 22A are connected to two ports only conditionally stipulated as inlet 41 and outlet 43 ports. The threaded leading portion is separated from the regulating portion by smooth bore cylindrical portion 22C. In some particular embodiments the regulating portion is adjacent to the leading portion as its extension. The regulating portion 22A can be threaded or smooth. Threaded regulating portion has the same pitch as the leading one.

[0076] A substantially cylindrical stem 20 is mounted into longitudinal tubular cavity of the body 22. The stem has a threaded portion 20C engaged with respective body leading thread 22E, adjacent to one end of smooth cylindrical portion 20D, the other end of which is adjacent to regulating portion 20B. In some particular embodiments the tread of the leading portion 20C is extended over the regulating portion 20B and has the same pitch as the leading one.

[0077] The preferred embodiment illustrated on FIG. 1 has mutually engaged leading portions of the body 22E and of the stem 20C. The leading portion of the body thread 22E is separated by substantially cylindrical portion 22C from the threaded regulating portion 22A. This threaded regulating portion 22A of the body 22 is engaged with threaded regulating portion 20B of the stem 20. The crest of the thread on the stem 20 is truncated tapering from major diameter of external thread to lesser than minor diameter of external thread with transition to front conical sealing surface 20A of the stem, which can tight the body seat 22D. A channel 40 is formed along the truncated thread of the stem 20 and the regulating portion of the body 22. This channel is connecting inlet 41 and outlet 43 and serves as a fluid path.

[0078] Similar to the embodiment shown on FIG. 1 is the valve pictured on FIG. 2. The main difference is the way of forming the flow path 40. In this embodiment the root of the stem's thread is tapering from major diameter of external thread to lesser than minor

diameter of external thread with transition to front ogival sealing portion **20A**. This portion seats and tightly seals corresponding body seat **22D**. The regulating portion **22A** of the body is threaded with matching the stem pitch internal thread. The crest of this thread is tapering from major diameter of the internal thread to lesser than minor diameter of the same thread transitioning to body sealing seat **22D**.

[0079] Another close to both discussed embodiments is interpreted on **FIG. 3**. The threaded stem is engaged with sliding fit into substantially smooth cylindrical regulation body portion **22A**. The flow path **40** is formed as channel with tapering cross-section between the surface of the smooth cylindrical regulating body portion **22A** and tapering threaded stem portion **20B**. This embodiment suggests technological and maintenance easiness. All embodiments explained on **FIGS. 1, 2, 3** have micrometric means **30** fixed to the stem for accurate positioning of the stem **20** into the body **22**, therefore very fine regulation of the cross-section of flow path **40**.

[0080] The basic concept of regulation for all above described valves is illustrated on **FIG. 4** by showing the main parts - body **22** and stem **20** of one generic embodiment - in four consecutive positions of engagement.

[0081] On **FIG.4-A** which represents “shut-off” position, the stem **20** is moved to the end of the thread and its front conic surface **20A** seals the corresponding surface **22D**, seen better on **FIG.4-B**, adjacent to inlet **41** or outlet **43** ports. The tight fit between **20A** and **22D** is separating the inlet and the outlet ports from the fluid path **40**, formed as a backlash or channel between the crest and roots of both threadedly engaged body **22** and stem **20**. The distance between the inlet port and outlet port includes at least one complete turn of the stem but preferably includes 3 to 15 or more peach steps corresponding to same quantity full rotations of the stem.

[0082] On **FIG.4-B** the stem **20** is shown after several turns backward from the “shut-off” position wherein the sealing surfaces **20A** and **22D** are separated. The port **41** is fully opened and a fluid path **40** is formed along the spiral line between the crest of the thread of stem **20** and the root of the thread in body **22**. It is well seen that the formed fluid path **40** have a changeable cross-section and length. The flow in fluid path is controlled therefore by the smallest cross-section of this channel and the friction of the fluid with channel walls.

[0083] On **FIG.4-C** the stem **20** is shown after several more turns backward. One end of the passage **40** is transformed to annular space between the stem **20** and the body **22**. The flow is controlled by the cross-section of the annular space defined between the front sealing surface of the stem and the internal surface of the body.

[0084] On **FIG.4-D** the stem is shown in completely opened position when the inlet and outlet ports are connected by full bore diameter which cross-section is bigger than any of the inlet or outlet ports.

[0085] It should be well understand that **Fig. 4** is illustrating the main concept of functioning of the valve according to the present invention irrespective of any particular embodiments shown further. From fully “shut-off” position on **FIG.4-A** when the flow is zero, through gradually enlarging fluid path cross-section and shortening its length leading to slow and gradually increasing flow on **Fig.4-B**, then to partially opened annular channel determining much bigger flow change on **FIG.4-C**, and finally, to fully opened full bore space determining the maximum flow at the given pressure difference between inlet and outlet ports on **FIG.4-D**. In order to minimize the axial force and cavitation effects of the flow, especially when a liquid is used as fluid, the side port **41** is more preferred to be used as inlet port and axial **43** as outlet port. However the use of the ports by opposite way could have its convenience for example when valve is used to control gas flow through rotameters. The indications “inlet port” and “outlet port” are more for better understanding, rather than functional necessity.

[0086] On **FIG. 5** are shown some generic shapes of cross-section of the fluid path **40**. The exhibited cases on **FIGS. 5-A,B,C,D,E,F** do not exhaust the multitude of the possible engagements and respective shapes of path **40**. The common feature for all of them is the change of the cross section of the fluid path as function of the length extended between the two ports.

[0087] **FIG. 6** represents an embodiment allowing easy manufacturing by casting or injection molding of the fine regulating sabot **21** having tight press-fit over the stem **20**. This sabot can be changed during regular maintenance of the valve not interfering with the integrity of the other more expensive parts of the valve. Appropriate material for the sabot **21** is a plastic or metal alloy with low coefficient of friction.

[0088] On FIG. 7 another version of the regulating part of the valve is interpreted. The leading part of the stem thread **20C** is separated from the regulating part **20B** by thin neck portion **20G**. The seal between the body and the stem is realized along the extended cylindrical portion **20D** of the stem, not evinced on the diagram. This valve is designed for very low to moderate flows. Advantageous of this design is the convenience of mass-manufacturing such type of threaded body and stem.

[0089] FIG. 8 shows another preferred embodiment of the valve upon present invention. The regulating portion of the body is substantially cylindrical and has sliding fit with the threaded stem. This embodiment can provide very good control for the lower flow range yet is constructed for high and very high flows at low pressure difference between the inlet and outlet ports. The annular space **45** around the stem **20** connected to the port **41** helps very high flows to be handled with considerable accuracy.

[0090] FIG. 9 delineates one more complete assembly of the valves depicted on FIG. 1, 2, 3. All coupling parts and mounting details are illustrated for better understanding of the construction and functioning of the valve. The body-insert **22B** has to be machined in fine and accurate manner from different but compatible with the body material as self-lubricated plastic or metal. The present invention does not intend to specify any particular materials, rather to take advantage of their known features. In this embodiment the regulating portion **20B** of the stem is separated from the leading one **20C** by smooth cylindrical portion **20D**. The surface of this portion is sealed by the pressure over the packing seal **27** being part of body-insert **22B**. The body-insert is made from above mentioned material with low coefficient of friction – nylon, molybdenum sulphide filled nylon, PTFE, PTE, polypropylene or alike. Pressurizing power over seal **27** is provided by bonnet **24**. Additional sealing is provided by O-ring **26** seated in the grove **20E**. The regulating portion **20B** of the stem **20** is truncated similar to the threads shown on FIG. 2 and is functioning the same manner.

[0091] FIG. 10 shows full assembly of a valve upon present invention in which the leading portion of the stem **20C** is separated from regulating portion **20B** only by cylindrical portion of the stem similar to one shown on FIG. 9, but no O-rings are used. The axial pressure over the seal **27** of elastic body-insert provided by bonnet **24** shrinks the diameter of the seal over the smooth surface **20D** of the stem, therefore seals the inner and outer cylindrical surfaces

without necessity of o-ring. The regulating portion of the stem is acting similarly to the one of the valve shown on **FIG. 3**. The “shut-off” function is executed in the position when non-threaded cylindrical portion of the stem is covering completely port **41**.

[0092] In both cases shown on **FIG. 9** and **FIG. 10** the valve has connecting fittings **42** and **44** for in-line assembly. It should be understand by one skilled in the art, that the same variety of regulating combinations between threaded stem and non threaded body or insert can be provided by threaded body and smooth stem upon technological and/or exploitation requirements.

[0093] All versions of the valve upon present invention shown and discussed above are capable of providing fine regulation of the fluid flow from very low to the maximum high level restricted only by diameters of inlet/outlet couple at a given pressure difference. This way the valve at the present invention is outperforming any needle-type or another construction valve in accuracy, precision and flow range. It should be understand that the spirit of the present invention includes any valve which partially or in full can regulate the flow by controlling the length and/or cross-section of the spiral backlash or channel formed along tapering truncated thread between inlet and outlet of the valve.